INITIAL OPERATION OF THE DECADE QUAD IN LAB MODE*

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Abstract

The Decade Quad NWE Simulator [1,2] will be in operation at the Arnold Engineering and Development Center in the fall of 1999. In its initial configuration, its four identical modules (Marx, transfer capacitor, coaxial water line and conical MITL) each terminate in plasma opening switch, large area bremsstrahlung (LAB) loads that combined will produce an x-ray dose of at least 16 krad (Si) over an area of at least 2250 cm^2. A validation test of the first conical MITL and POS load driven by the Decade Module 2 at Maxwell Physics International has successfully produced an x-ray dose consistent with these performance requirements. The initial assembly and check out of the Decade Quad pulsed power subsystems has been completed and is reported herein. Initial x-ray tests are currently underway.

I. INTRODUCTION

The Decade Program began in the late 1980's to provide the Department of Defense with an aboveground testing (AGT) capability for NWE assessments of strategic and tactical weapon systems up to the ensemble and small system level. Test objects were to be exposed to fluence levels three to ten times the level that AGT simulators could then produce. With the goal of fluence levels ten times greater than that available circa 1980, the program became known as the Decade Program. With the 1993 moratorium on underground testing, the Decade program became the DoD's future test facility for AGTs.

Decade was originally to consist of sixteen modules stacked in groups of four "Quads" (Fig. 1). If required by funding constraints this design would allow DTRA to build the Decade machine in stages. This year Maxwell Physics International will deliver the first Quad at Arnold Engineering Development Center in Tennessee. The initial assembly and pulsed power proof tests are now complete. Initial x-ray operation is underway. The key performance and operational specifications for the LAB configuration are given in Table I.

Figure 1. The 2.5 MJ Decade Quad x-ray NWE simulator will be in operation at Arnold Engineering and Development Center in Tennessee starting in the fall of 1999. In its original configuration it will have a bremsstrahlung load that produces > 16 krad (Si) over an area of at least 2250 cm^2 with better than 2:1 uniformity.

Table I: Summary of Key DQ LAB Performance and Operational Parameters

X-ray	Electrical (85 kV charge)	Operational
Dose: 20 ± 10% krad (Si)	Stored Energy: 2.3 MJ	≥ 12 shots per 40-hr week
Area: 2,500 ± 10% cm^2*	Peak POS Current: 1.8 MA	≥ 60%/yr availability
FWHM: ≤ 45 ns	Voltage @ POS: 3 MV	≥ 30 shots between 5-day maintenance
End-Pt Energy: ≤ 1.8 MeV	Ensemble Jitter: ≤ 4 ns**	≥ 360 total shots/yr
Ensemble Jitter: ≤ 4 ns		

* Target Aspect Ratio: 1.2:1.0 ** Time to 1 MA on each module
Uniformity: ≥ 2:1

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14. ABSTRACT
The Decade Quad NWE Simulator [1,2] will be in operation at the Arnold Engineering and Development Center in the fall of 1999. In its initial configuration, its four identical modules (Marx, transfer capacitor, coaxial water line and conical MITL) each terminate in plasma opening switch, large area bremsstrahhmg (LAB) loads that combined will produce an x-ray dose of at least 16 krad (Si) over an area of at least 2250 cm*. A validation test of the first conical MITL and POS load driven by the Decade Module 2 at Maxwell Physics International has successfully produced an x-ray dose consistent with these performance requirements. The initial assembly and check out of the Decade Quad pulsed power subsystems has been completed and is reported herein. Initial x-ray tests are currently underway.

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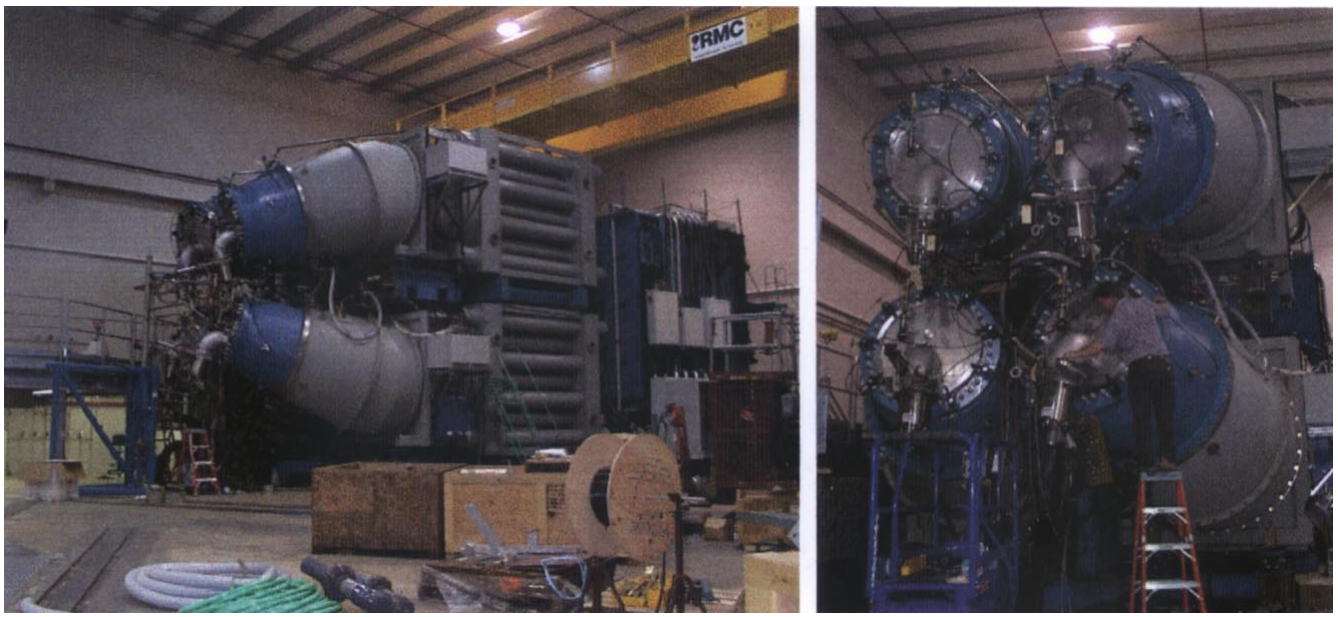


Figure 2. Decade Quad configuration for the pulsed power checkout. The Marx, TC and Output Switch pulsed power checkout was conducted into resistive loads at the end of the Output Lines. These loads have since been replaced with the MITLs and LAB loads in preparation for the x-ray output validation tests that are currently in progress.

II. INITIAL DECADE QUAD PULSED POWER TESTS

A. Description of Tests and Configurations

Fig. 2 shows two views of the four modules that constitute a Quad. The main components from primary store to load are the Marx, the transfer capacitor (TC) and triggered output switches, the output line (OL) and vacuum interface. (Diverter switches are located on both fore- and aft-ends of each TC.) After the pulsed power check out the four conical magnetically insulated transmission lines (MITL), plasma opening switches (POS) and diode loads will be installed.

For the pulsed power check out these front ends were replaced with a short-circuit load just downstream from the high voltage insulator at the ends of the coaxial output lines. Tests were done at "one half power" (65 kV Marx charge) to establish the Marx and output switch gas pressures and the trigger timings necessary to achieve efficient power flow. Voltage and current pulse shapes were recorded on each Marx submodule (six Marx submodules per Marx module) each of the four TCs and each output switch (six switches per TC). Module-to-module jitter was measured but will be largely ignored until "full power operation" (85 kV charge) is established into the diode loads. (Jitter should improve as the charge voltage is increased for full power operation.)

B. Results of Pulsed Power Tests

1) Marx Tests

Initially, the Marx and TCs were isolated by shorting the diverters on the TC input and over-pressurizing the output switches on the TC output. The total Marx module #1 current (sum of the module #1 six subMarx current monitors) is shown overlaid below for 10 shots with all four modules fired simultaneously charged to ±65 kV.

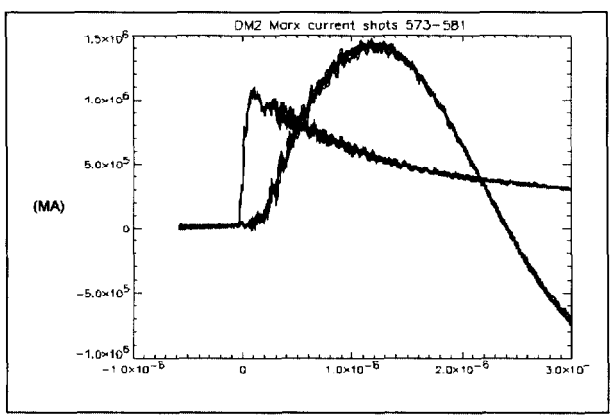


Figure 3. Total Marx module #1 current and trigger Marx waveforms at 65 kV charge (all four modules fired simultaneously). In this instance the jitter is ~20% higher than that seen on DM2 in the same configuration. Jitter should improve as the charge voltage increases toward full power at 85 kV.

2) TC and Output Switch Tests

A number of problems were encountered during the initial operations, many arising from various contaminations in the oil, SF6 and water subsystems. The water contamination resulted in breakdowns in the transfer capacitors and tracking of the Lucite envelopes on the output switches. These difficulties precluded operation of all four modules simultaneously into the short-circuit loads. (Modules were triggered simultaneously in pairs, and all four will be fired simultaneously during the initial x-ray tests.) Modules #3 and #4 had the largest number of shots (14 shots on #3, 9 shots on #4) accumulated after most of the contamination problems were identified and mitigated. Plots of the current measured by B-dot monitors in the oil section for these shots are shown in Fig. 4. At this writing, the monitors for the Decade modules have not been calibrated. These signals have been normalized to have an average peak value of 1.0. The current for DM2 (Fig. 4c) is in megaamperes. The performance of DM2 is typical for the single module operating at 85 kV, 3.3 ns of jitter in the time when the current into the switch passes 1.1 MA. The performance seen on Decade module #4 is better than this, showing 2.5 ns of jitter in the time when the current passes a similar fraction of the peak value. Module #3 on the other hand shows greater jitter. The majority of this jitter is in the firing time of the trigger generator. This was traced to jitter in a PT55, one of the generators in the trigger chain for the output switches. If this effect is subtracted out, the jitter in the time between passing 5% and 61% is 2.2 ns for module #3. It should be noted that for these shots, the Marx jitter was noticeably better than that seen in the previous Marx tests.

In summary, the pulsed power systems of all four Decade modules have been operated at approximately half power (65 kV Marx charge as compared to 85 kV for normal operation). The system performance is not at specification yet, but shakedown of this large complex system of four independent pulsed power modules is proceeding. Indications are that the system can be tuned to meet design specifications and will deliver the required waveform to the Plasma Opening Switch to generate the projected radiation output.

III. INITIAL X-RAY OUTPUT MEASUREMENTS

Prior to final installation and test at AEDC the new conical MITLs, POS and diode/x-ray converter were tested on the DM2 module at MPI, San Leandro, California (Fig. 5).

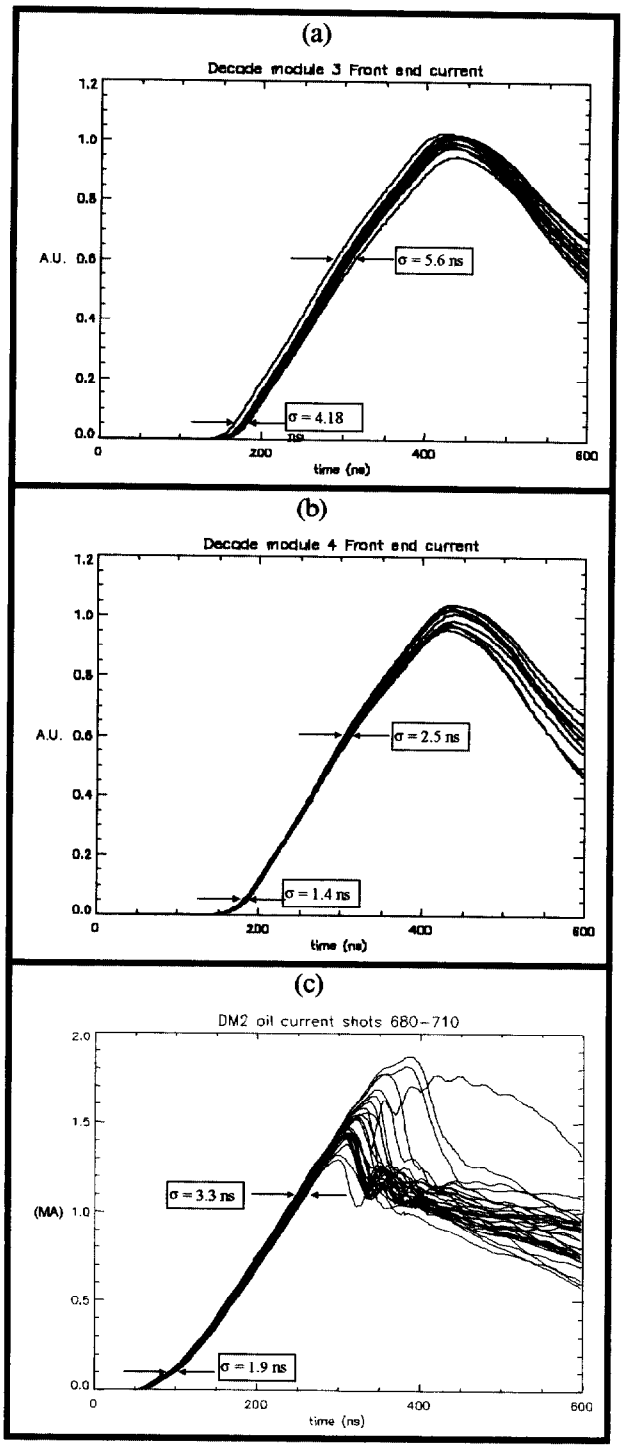
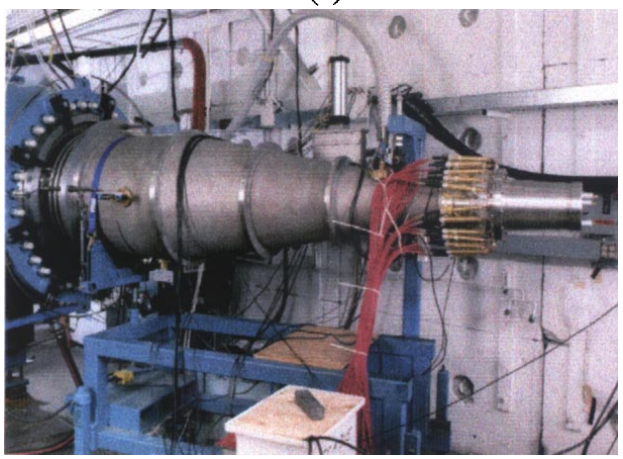


Figure 4. (a) Overlay of Decade Quad module #3 current to the front-end for 14 half-power (±65 kV charge) discharges. (b) Overlay of DQ module #4 current to the front-end for 9 half-power discharges. (c) DM2 current overlay into similar load at full (±85 kV charge) power. Indications are that the Marx trigger, Marx switch, and output switch systems can be tuned to meet design specifications and will deliver the required waveform to the Plasma Opening Switch to generate the projected radiation output.

The purpose of this exercise was to identify and correct any mechanical deficiencies and to verify that the small deviations in the electrical design (from the designs previously proven in DM1 qualification tests) did not adversely affect x-ray production.

(a)



(b)

Figure 5. (a) First article MITL and POS/load mounted on DM2. (b) DQ front-end assembled in preparation for initial x-ray tests at AEDC.

Results from this brief, 15-shot test (Fig. 6) showed that the more conservative conical MITL design (higher impedance and shorter length) preserves the overall inductance. System impedance was consistently better than DM1 results for a given conducted current. This opens up options for improved performance, possibly allowing operation at higher conducted currents (more energy stored) which should result in increased output.

On the initial trial at half power, DQ Module #4 produced an equivalent yield of 11 krad (Fig. 7). This is the output expected at 65 kV charge. Through June the four modules have been fired individually and each has produced this dose level. These encouraging results have established an initial point of departure and charge voltage will now be increased to full power.

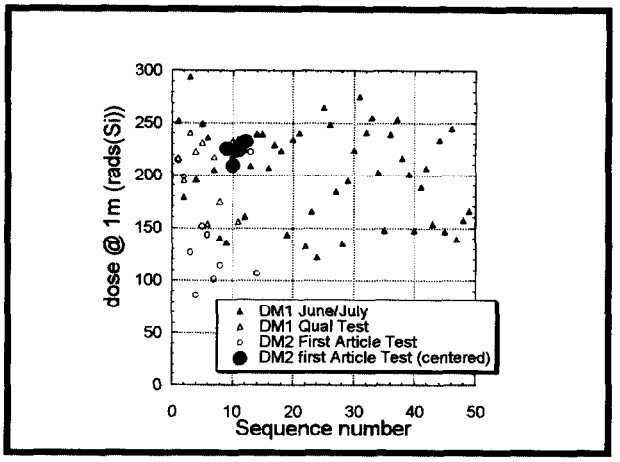


Figure 6. The first article dose at 1 m was measured on the high end of DM1 Qualification Test results. These DM1 data average to the minimum x-ray performance specification: 16 krad (Si) over 2250 cm^2.

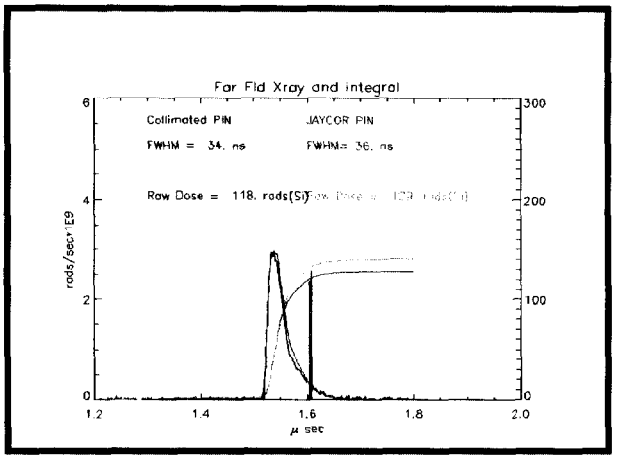


Figure 7. On the initial trial at half power (65 kV charge) DQ module #4 produced an equivalent yield on 11 krad. (Si).

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V. REFERENCES

[1] P. Sincerny, S. Ashby, K. Childers, C. Deeney, D. Drury, J. Goyer, D. Kortbawi, I. Roth, C. Stallings, L. Schlitt, "The Decade High Power Generator", in *Proc. Ninth IEEE Intl. Pulsed Power Conf.*, Albuquerque, NM, 1993, p. 880.

[2] D. Price, K. Childers, P. Creely, D. Kortbawi, Y. Jeon, D. Hopwood, J. Meachum, C. Parks, P. Sincerny, T. Tucker, LCDR C. Wellington and K. Ware, "The Decade Quad NWE Simulator", in *Proc. HEART'99*, Monterey, CA., 1999.